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ORIGINAL PAPER

Standardization of harvesting age of bamboo shoots with respect to nutritional and anti-nutritional components

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Abstract: Bamboo shoots can be harvested at different ages but the data on the changes in nutritional composition with age are scanty. We standardized harvesting age of bamboo shoots in central India to obtain best quality produce with respect to nutritional composition. The shoots harvested on different days (2–20 days after emergence from ground) were analyzed for their nutritional (dietary fibres, carbohydrates, proteins, total phenols, ascorbic acid, sodium, potassium, phosphorus, calcium, magnesium and phenolic acids) and anti nutritional (cyanogen) constituents. A significant variation (at $p \leq 0.5$) was observed in the nutritional composition of shoots of *Dendrocalamus asper*, *D. strictus* and *Bambusa tulda* harvested at different days. An overall decrease was observed in proteins and total phenols while dietary fibres and carbohydrates increased with ages. Significant variation (at $p \leq 0.5$) was also observed in phenolic acids while minerals did not vary significantly. Results revealed that the optimum harvesting age for *D. asper*, *D. strictus* and *B. tulda* was on 10–14 days, 6–10 days and 10–16 days (after emergence from the ground) respectively. These results can be used to obtain quality bamboo shoots.

Keywords: Bamboo shoots; harvesting; nutritional status; central India; phenolic acids; anti-nutrient

Introduction

Bamboo shoots are young and tender culms of bamboo that are consumed for various food items after harvesting (Bal et al. 2008; Pande et al. 2008). There are a number of bamboo species available in India and many of the species are used for edible purpose. *Dendrocalamus strictus* and *Bambusa bambos* are the common species occurring in central India. The other species are *B. nutans*, *B. tulda*, *D. giganteus* and *D. hamiltonii*. However, *Dendrocalamus asper*, an important edible species of Thailand (Fu et al. 1987), was introduced in India for shoot production. In central India, bamboos have not been commercially cultivated for its edible shoot production. Generally people harvest bamboo shoots from nearby forests. However, in some places bamboo shoots were also harvested from cultivated sources (plantations and home gardens). The shoots are consumed in raw, dried, canned, boiled and fermented form in a short period being seasonal and perishable.

Worldwide, bamboos have an estimated potential value of approximately US $100 million. In the international market, China earns US$130 million every year from exports of edible bamboo shoot. The US imports around 44,000 t of edible bamboo shoot, accounting for 14.5% of the total world imports (Lobovikov 2003). At present over two million tonnes of edible bamboo shoots are consumed in the world in each year (Yang et al. 2008), and about 20–30 million t of bamboo shoots are utilized for production of canned bamboo shoots annually (Bhatt et al. 2003; 2005 a, b). India's bamboo value is currently estimated at US$ 40 million. However, the market potential of bamboo in India will increase to US$ 520 million by 2015 (Farooquee et al. 2007).

Various nutritional constituents like acids, proteins, carbohydrates, starch, fat, dietary fibre, vitamins and minerals have been systematically analyzed and reported by various authors (Anonymous 2004; Bhatt et al. 2005a; Nirmala et al. 2008). The shoots are low in fat content, but contain considerable amount of carbohydrate, potassium, pyridoxine, thiamine, riboflavin, niacin, ascorbic acid, phenolic acids and dietary fibres like hemicelluloses, cellulose, pectin and lignin (Tripathi 1998; Park et al. 2009). Phenolic acids are a unique category of phytochemicals having vast potential with respect to health benefiting properties. The existing literature on biological activities reports that products with rich polyphenols have positive effects on human health, especially in reducing the incidence of cardiovascular diseases and some types of cancer (Oboh 2008). Besides, bamboo shoots

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also contain cyanogenic glycoside i.e. taxiphyllin, which is toxic in nature (Ferreira et al. 1995; Fu et al. 2002; Sarangthem et al. 2003; Pandey et al. 2011a; EFSA 2004). Hydrocyanic acid (HCN) will start to break down and release cyanide when plant tissue is crushed. Many authors and organizations (Simeonova et al. 2004; ATSDR 2006; Satya et al. 2010; NMBA 2009) have assessed these glycosides. The amount of cyanides in shoots varies with different species. Generally, the amount of HCN was from 0.3% to 0.8% in the shoots (Poulton 1983; Tripathi 1998; Anonymous 2004). Haque et al. (2002) reported that the amount of HCN is 0.16% in the tip, and 0.01% at the base of shoots. The new shoots have no acrid taste and are good for human consumption. However, these glycosides increase with the age/maturity of shoots (Anonymous 2004). Thus, it is necessary to harvest shoots, at right time. The information regarding the harvesting ages of bamboo shoots is scarce and needs scientific validation with respect to the nutritional changes with ages. Therefore, present study was undertaken to standardize the harvesting age of bamboo shoots in central India to obtain best quality produce.

Materials and methods

The species selected for the study were *D. asper*, *B. tulda* and *D. strictus*. The study was carried out at the Non Wood Forest Produce (NWFP) Division of Tropical Forest Research Institute (TFRI), Jabalpur (India) during July−August, 2010. The newly emerging shoots at different ages (2–20 days), were collected from the NWFP nursery and Botanical Garden of TFRI during morning hours as transpiration is less. Length, diameter at the base, and weight of fresh shoots before and after removing sheaths were recorded to determine the percentage of edible portion. The shoots from *D. asper* of 8–18 days, *D. strictus* of 2–16 days and *B. tulda* of 4–20 days old were selected. After peeling off the sheaths, the inner soft portion of shoots was taken and analyzed for their nutritional, anti-nutritional and phenolic acid composition to determine the suitable ages for harvesting of bamboo shoots. The nutritional analysis of the shoots was determined by using standard established methods.

Estimation of carbohydrates

The carbohydrate content was measured by hydrolyzing the polysaccharides into simple sugars by acid hydrolysis and estimating the resultant monosaccharides spectrophotometrically by Anthrone's method (Hedge et al. 1962). The 0.1 g of bamboo shoots was hydrolyzed by keeping in boiling water bath for 3 hours in 5 mL of 2.5 N hydrochloric acid (HCl), cooled to room temperature, neutralized with solid sodium carbonate (Na_2CO_3) until the effervescence ceases. The volume was made upto 100 mL with distilled water. The filtrate (0.5 mL) and glucose standards were taken. The volume was made upto 1 mL with distilled water and 4 mL of anthrone reagent was added. The solutions were then kept in boiling water bath for 8 min and absorbance was measured at 630 nm against blank. The standard curve was prepared using solutions of glucose of 0−1.0 mL of 100 $\mu g \cdot mL^{-1}$ stock solution in distilled water. The amount of carbohydrate (g) in the sample was then calculated with the help of standard curve.

Estimation of proteins

The protein content in the shoots was determined by the Lowry's method (Lowry et al. 1951). Extraction was carried out with phosphate buffer (2 M, 7.4 pH). The 0.5 g of sample was grinded well in 5−10 mL of buffer, centrifuged and the supernatant was taken for estimation. The supernatant (0.2 mL) and bovine serum albumin solution (BSA, standard protein) were taken, and volume was made upto 1 mL with distilled water, mixed with 5 mL of alkaline copper solution and allowed to stand for 10 min. The 0.5 mL of Folin-Ciocalteau reagent was then added in the tubes that were incubated at room temperature in dark for 30 min and absorbance was measured at 660 nm against blank. The standard curve was prepared by using solutions of BSA in a range of 0−1.0 mL of 200 $\mu g \cdot mL^{-1}$ stock solution in distilled water. The amount of protein (g) in the sample was then calculated from the standard curve.

Estimation of total phenols

Total phenols were determined by Folin Ciocalteau method (McDonald et al. 2001). The 0.5-g bamboo shoot was extracted in 80% ethanol and the homogenate was centrifuged. The supernatant was evaporated to dryness and residue was dissolved in a known volume of distilled water (5−15 mL). The extract (0.2 mL) and catechol (standard phenolic compound) were taken separately. The volume was made upto 3 mL with distilled water. The 0.5 mL of Folin Ciocalteau reagent was then added and left for 3 min. The 3 mL of 20% Na_2CO_3 was then added. The mixtures were kept in water bath for exactly 1 minute and the total phenols were determined by measuring the absorbance at 650 nm against blank. The standard curve was prepared using solutions of catechol in a range of 10−100 $\mu g \cdot mL^{-1}$ in distilled water. The amount of phenols (g) in the sample was then calculated from the standard curve.

Estimation of cyanogens

Cyanogens were estimated as hydrocyanic acid equivalents which evolve from the samples (Hogg et al. 1942). 1 g of sample was homogenized in 25 mL of water with 3–4 drops of chloroform and placed in a 500-mL conical flask. A filter paper strip (in size of 10−12 cm × 0.5 cm) saturated with alkaline picrate solution was hanged in the flask and incubated at room temperature for 20–24 hours. The sodium picrate present in the filter paper is reduced to reddish compound in proportion to the amount of hydrocyanic acid evolved. The filter paper strip was then placed in a test tube containing 10 mL of water for 2 min. The strip was removed and absorbance of solution was measured at 625 nm. The standard curve was prepared using solutions of sodium cyanide (NaCN) in a range of 0–3.0 mL of 100 $\mu g \cdot mL^{-1}$ in distilled water. The amount of cyanogens in the sample was

then calculated as hydrogen cyanide equivalent (g) from the standard curve.

Estimation of ascorbic acid

The ascorbic acid content in the bamboo shoots was determined volumetrically (Raghu et al. 2007) by titrating with 2, 6 dichloro-phenol indophenol dye. The 0.5 g of sample was extracted in 0.4% oxalic acid and made upto a known volume (10–20 mL) and centrifuged. To 5 mL of supernatant, 10 mL of 0.4% oxalic acid was added and titrated. The amount of dye consumed is equivalent to the amount of ascorbic acid present in the sample.

Mineral estimation (Jacobs 1999)

Digestion of the sample

The 0.5 g of sample was taken in a 5-mL conical flask, 5 mL of conc. nitric acid (HNO_3) was then added and heated at high temperature until acid was evaporated, and then 5 mL of ternary mixture was added (H_2SO_4, $HClO_4$ and HNO_3 in the ratio 1:4:10). The mixture was heated until the digestion material becomes clear. The 5-mL hydrochloric acid (HCl) was added and the volume was made upto 100 mL with distilled water. This digestion extract was then used for further analysis.

Estimation of sodium and potassium

Sodium and Potassium were estimated by using flame photometer. Standard curves of sodium and potassium were made and the amount of sodium and potassium in the samples was calculated from the standard curve.

Estimation of phosphorus

To 5 mL of extract, 10 mL of vanadomolybdate solution was added and volume was made up to 50 mL with distilled water. The standard curve was prepared by using dihydrogen potassium phosphate (KH_2PO_4) in a range of 0.02–0.2 $\mu g \cdot mL^{-1}$. The solutions were allowed to stand for 10 min and absorbance was measured at 470 nm against blank. The amount of phosphorus in the samples was calculated from the standard curve.

Estimation of calcium

The 5 mL of extract was taken and 20 mL of distilled water was added, followed by 10 drops of sodium cyanide, 10 drops hydroxylamine hydrochloride and 1 drop of 1% potassium ferricyanide solution (yellow colour develops). To the solution, 10% sodium hydroxide was added till yellow colour disappears. A pinch of mureoxide powder (indicator) was added to the resultant solution (pink colour develops) and titrated with EDTA (0.02 N) till the colour of solutions changes from pink to purple. The amount of EDTA consumed is equivalent to the amount of calcium present in the sample and expressed as sample (g) per 100 g.

Estimation of total Calcium and Magnesium

The 5 mL of extract was taken and 20 mL of distilled water was added, followed by 10 drops of sodium cyanide, 10 drops hydroxylamine hydrochloride and 1 drop of potassium ferricyanide (yellow colour develops). Buffer solution (NH_4Cl+NH_3) was then added till colour disappears. The 2-3 drops of EBT (Erichrome black T) indicator was added (blue colour develops) and titrated with EDTA (0.02N) till colour changes from blue to grey. The amount of EDTA consumed is equivalent to the total amount of calcium and magnesium present in the sample and expressed as sample (g) per 100 g. The amount of magnesium was calculated by subtracting the amount of calcium from the total calcium and magnesium content.

Estimation of phenolic acids

Phenolic acids content in bamboo shoots was determined by using reverse phase high pressure liquid chromatography (Shrivastava et al. 2009).

Sample and standard preparations

The 2.5 g of sample (fresh bamboo shoot) was taken in a conical flask containing 50 mL of 2 N hydrochloric acid (HCl). The flask was then kept in a boiling water bath for 30 min, cooled and filtered. The filtrate was transferred to a separating funnel and extracted with 100 mL (50, 25 and 25 mL) of diethyl ether. The combined ether layer was washed with distilled water and dried over anhydrous sodium sulphate. The residue thus obtained was dissolved in 10 mL of HPLC grade methanol and filtered through a 0.22-μm disc filter before injecting in HPLC. Standard solutions (1 $mg \cdot mL^{-1}$) of gallic acid, vanillic acid, caffeic acid, chlorogenic acid and ellagic acid (Sigma aldrich) were prepared by dissolving in HPLC grade methanol and filtered through a 0.22-μm disc filter.

Chromatographic equipment and conditions

A Waters (Milford, USA) gradient HPLC instrument equipped with two 515 pumps and controlled by an interface module PC2, manual injector valve (Rheodyne), reverse phase C18 (100 mm× 4.6 mm i.d.) × bridge HPLC column (Waters, Milford, USA) and Waters 2996 PDA (Photo Diode Array) detector was used for HPLC analysis. Waters Empower software was used to control the equipment and analyze the data. Mobile phase consisted of water, methanol and acetic acid in the ratio of 60:40:0.4 having a flow rate of 1.0 $mL \cdot min^{-1}$. The 5 μL of sample and standard were injected.

Statistical analysis

Data were subjected to statistical analysis using SPSS (Version 14.0) software. Data are expressed as mean ± SD (n=3). All values are on fresh weight basis. One way analysis of variance (ANOVA) was performed. Statistically best treatment was determined using Duncan's Multiple Range Test at $p < 0.05$ level of significance.

Results and discussion

Edible portion

The edible portion in bamboo shoots of all the three species studied initially increased and then decreased with ages (Table 1).

Early harvest may provide very small shoots in size with less edible portion and more sheaths, while late harvesting may result in the shoots being woody and tough. On an average age, the edible portion was maximum in *D. asper* (48.66%), followed by *B. tulda* (47.41%) and *D. strictus* (37.51%), (Fig. 1). The newly emerged shoots are soft and crispy. If shoots are not harvested at right time, they will develop an acrid flavour due to cyanogenic glycoside called taxiphyllin. Taxiphyllin is turned on by the hydrolytic enzyme: α-glycosidase, upon disruption of the plant cell (Ermans et al. 1980; Nahrstedt 1993). The new shoots are almost free from acridity and are brilliant for human consumption.

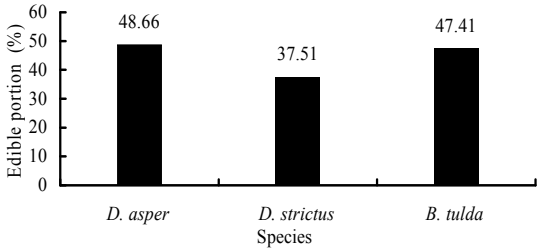

Fig. 1 Variation in edible portion of bamboo shoots of different species at optimum harvesting days

Table 1. Percentage of edible portion of shoots of *Dendrocalamus asper*, *D. strictus* and *B.tulda* at different optimum harvesting ages

Species	2 day	4 day	6 day	8 day	10 day	12 day	14 day	16 day	18 day	20 day
D. asper	-	-	-	46.81 ±3.61 a	51.53 ±8.19 a	53.50 ±8.48 a	52.60 ±5.21 a	52.30 ±6.08 a	48.70 ±8.84 a	-
D. strictus	16.24 ±5.92 d	36.65 ±5.96 c	57.63 ±7.31 a,b	59.24 ±7.20 a,b	59.60 ±7.70 a,b	62.23 ±6.59a	59.28 ±8.32 a,b	47.53 ±9.39 b,c	-	-
B. tulda	-	24.53 ±4.04 e	32.73 ±6.43 d, e	38.97 ±6.04 b,c,d	41.73 ±3.51 b,c,d	45.04 ±5.99 a,b,c	53.72 ±4.68 a	49.91 ±6.34 a,b	42.76 ±4.39 b,c,d	35.14 ±5.88 c,d

Notes: Data presented as mean ± SD. Values denoted by different letters differ significantly at $p \leq 0.05$.

Nutritional composition

The nutrients analyzed include crude fibre (consisting mainly of cellulose and lignin), carbohydrates, proteins and total phenols (Table 2). The contents of the fibre and carbohydrate increased with shoot ages (Nirmala et al. 2007). The fibre and carbohydrate contents were minimum in *D. asper* (2.30% and 1.87%) while maximum in *B. tulda* (3.02% and 2.70%). The lower fibre content of *D. asper* makes shoots more palatable. Proteins and total phenols contents showed an overall decrease with the shoot ages. The proteins and total phenols contents were maximum in *D. strictus* (1.35 % and 2.26%) and alike in *D. asper* (1.17% and 1.11%) and *B. tulda* (1.16% and 1.35%). Variation in nutrient composition of different bamboo shoots (average of optimum harvesting days) has been observed (Fig. 2). Results revealed that *D. strictus* and *B. tulda* have better nutritional composition than *D. asper* (edible bamboo species from Thailand grown in India).

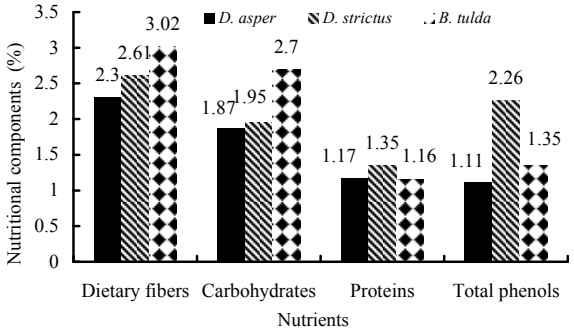

Fig. 2 Variation in nutritional components of bamboo shoots at optimum harvesting days

Table 2. Nutrient composition (g·100g^{-1}) in shoots of *Dendrocalamus asper, D. strictus* and *B. tulda* at different optimum harvesting ages

Species	Constituent	2 day	4 day	6 day	8 day	10 day	12 day	14 day	16 day	18 day	20 day
D. asper	Dietary fibers	-	-	-	0.72 ±0.03 f	1.68 ±0.04 e	2.34 ±0.04 d	2.89 ±0.03 c	3.35 ±0.05 b	3.86 ±0.03 a	-
	Carbohydrates	-	-	-	1.44 ±0.20 c	1.60±0.08 b c	1.90 ±0.23 a, b	2.12 ±0.28 a	2.13 ±0.22 a	2.21 ±0.17 a	-
	Proteins	-	-	-	1.21 ±0.10 a	1.2 ±0.10 a	1.18 ±0.09 a	1.14 ±0.19 a	1.10 ±0.15 a	0.86 ±0.19 b	-
	Total phenols	-	-	-	0.77 ±0.04 d,e	0.92 ±0.12 c	1.32 ±0.10 a	1.09 ±0.15 b	0.89 ±0.15 c, d	0.71 ±0.13 e	-
D. strictus	Dietary fibers	0.52 ±0.04 h	0.92 ±0.04 g	1.59±0.04 f	2.87 ±0.03 e	3.36 ±0.06 d	3.96 ±0.05 c	4.68 ±0.03 b	5.46 ±0.04 a	-	-
	Carbohydrates	1.42 ±0.16 f	1.55 ±0.18 e, f	1.83±0.19 d, e	1.91 ±0.18 c, d	2.12 ±0.17 b, c, d	2.18 ±0.23 a, b, c	2.27 ±0.19 a, b	2.46 ±0.12 a	-	-
	Proteins	1.72 ±0.15 a	1.6 ±0.13 a	1.48 ±0.19 a, b	1.34 ±0.16 b, c	1.22 ±0.25 c, d	1.01 ±0.18 d, e	0.93 ±0.15 e	0.8 ±0.14 e	-	-
	Total phenols	1.92 ±0.21 a	2.4 ±0.16 b	2.97 ±0.19 c	2.04 ±0.18 c, d	1.77 ±0.19 d, e	1.65 ±0.19 e	1.32 ±0.17 f	1.04 ±0.20 g	-	-
B. tulda	Dietary fibers	-	0.79 ±0.05 i	1.22 ±0.03 h	1.77 ±0.03 g	2.18 ±0.03 f	2.71 ±0.05 e	3.22 ±0.03 d	3.98 ±0.04 c	4.57 ±0.03 b	5.20 ±0.03 a
	Carbohydrates	-	1.91 ±0.19 e	1.97 ±0.19 e	2.16 ±0.18 e	2.21 ±0.24 d, e	2.51 ±0.14 c, e	2.75 ±0.14 e	3.31 ±0.15 b	3.7 ±0.17 a	3.89 ±0.18 a
	Proteins	-	0.51 ±0.20 c	0.43 ±0.18 c	0.95 ±0.19 b	1.06 ±0.21 a, b	1.13 ±0.17 a, b	1.29 ±0.14 a	1.15 ±0.20 a, b	1.02 ±0.21 a, b	0.89 ±0.27 a
	Total phenols	-	0.57 ±0.21 f	0.62 ±0.27 e, f	0.96 ±0.25 d, e, f	1.15 ±0.34 d	1.11 ±0.38 d, e	1.33 ±0.22 c, d	1.81 ±0.27 b, c	2.51 ±0.14 a	1.86 ±.36 b

Notes: Data presented as mean ± SD (n=3). Values denoted by different letters differ significantly at $p \leq 0.05$.

The change in nutrient composition of bamboo shoots with age could be due to an increase in metabolic activity by photosynthesis in the sunlight. This is because the shoot emerges from the ground to develop chlorophyll (Nirmala et al. 2007). Our

findings are in harmony with the findings of other researchers. Hu et al. (1986) reported a reduction in contents of proteins, carbohydrates, fat, vitamins and mineral in the older shoots of *Phyllostachys pubescens* as compared with the underground shoots. Nirmala et al. (2007, 2008) and Hu et al. (1986) found that the nutrient components of the shoots were depleted with ages, but dietary fibre and moisture contents increased. Carbohydrate, protein and fibre contents are responsible for the taste of bamboo shoots. The protein content increases the deliciousness of shoots while fibre and tannin were decreased (Xia 2006).

Mineral composition

Mineral composition was not significantly affected with the ages of shoots (Table 3). However, potassium and calcium showed significant ($p \leq 0.5$) variation with shoot ages. The potassium concentration was decreased with the shoot ages in *D. asper* and *D. strictus* while in *B. tulda*, the concentration was initially increased and then decreased with ages. The maximum potassium concentration in *D. asper* was found in shoots of 8−12 days old, *D. strictus* in shoots of 2−8 days old and *B. tulda* in shoots of 8−10 days old. On an average, the potassium content was 0.48% in *D. asper* and *D. strictus* and 0.35% in *B. tulda* (Fig. 3). Mineral content of bamboo shoots from central India was higher than that of the shoots from northern part of India (Nirmala et al. 2007). The calcium concentration decreased with the shoot age in *D. asper* and *D. strictus*, and was found to increase in *B. tulda*. The bamboo shoots with relatively high content of minerals may have therapeutic value. Potassium and magnesium are known to decrease blood pressure. Calcium is a major factor for strong bones and plays a part in muscle contraction. Vitamin C content was very little in shoots, accounting for about 0.006%. No significant difference was observed in the concentration of vitamin C with the different ages of shoots.

Table 3. Mineral and Vitamin C composition (g·100g^{-1}) in shoots of *Dendrocalamus asper*, *D. strictus* and *B. tulda* at different optimum harvesting ages

Species	Constituent	2 day	4 day	6 day	8 day	10 day	12 day	14 day	16 day	18 day	20 day
D. asper	Vit. C	-	-	-	0.006 ±0.0 a	0.006 ±0.0 a	0.006 ±0.0 a	0.006 ±0.0 a	0.006 ±0.0 a	0.006 ±0.0 a	-
	Na	-	-	-	0.04 ±0.01 a,b	0.04 ±0.02 a	0.06 ±0.01 a	0.05 ±0.02 a	0.04 ±0.01 a, b	0.02 ±0.0 b	-
	K	-	-	-	0.49 ±0.02 a	0.5 ±0.02 a	0.5 ±0.01 a	0.45 ±0.02 b	0.42 ±0.02 c	0.4 ±0.0 c	-
	P	-	-	-	0.01 ±0.01 a	0.01 ±0.01 a	0.01 ±0.0 a	0.01 ±0.0 a	0.01 ±0.0 a	0.01 ±0.0 a	-
	Ca	-	-	-	0.16 ±0.01 a	0.16 ±0.02 a	0.16 ±0.0 a	0.15 ±0.01 a, b	0.14 ±0.02 b, c	0.14 ±0.02 c	-
	Mg	-	-	-	0.12 ±0.01 a	0.12 ±0.02 a	0.12 ±0.0 a	0.12 ±0.01 a	0.12 ±0.02 a	0.12 ±0.03 a	-
D. strictus	Vit. C	0.006± .0 a	0.006± 0.0 a	0.006±0.0 a	0.006 ±0.0 a	0.006 ±0.0 a	0.006 ±0.0 a	0.006 ±0.0 a	0.006 ±0.0 a	-	-
	Na	0.03± 0.01 c	0.03± 0.01 c	0.04 ±0.01 a, b	0.04 ±0.01 a	0.03 ±0.01 c	0.03 ±0.0 b, c	0.03 ±0.0 b, c	0.03 ±0.0 b, c	-	-
	K	0.52± 0.03 a	0.5±0.02 a	0.5 ±0.01 a	0.49 ±0.0 a	0.45 ±0.03 b	0.4 ±0.0 c	0.39 ±0.02 c, d	0.36 ±0.0 d	-	-
	P	0.01±0.0 a	0.01±0.0 a	0.01 ±0.0 a	0.01 ±0.0 a	0.01 ±0.0 a	0.01 ±0.0 a	0.01 ±0.0 a	0.01 ±0.0 a	-	-
	Ca	0.16± 0.01 a	0.16± 0.02 a	0.14 ±0.02 a, b	0.15 ±0.01 a, b	0.14 ±0.01 b	0.14 ±0.01 b	0.14 ±0.02 b	0.12 ±0.02 c	-	-
	Mg	0.15± 0.01 a	0.15± 0.02 a	0.15 ±0.01 a	0.15 ±0.01 a	0.15 ±0.01 a	0.15 ±0.01 a	0.15 ±0.02 a	0.12 ±0.01 b	-	-
B. tulda	Vit. C	-	0.006± 0.0 a	0.006 ±0.0 a	0.006 ±0.0 a	0.006 ±0.0 a	0.006 ±0.0 a	0.006 ±0.0 a	0.006 ±0.0 a	0.006 ±0.0 a	0.006 ±0.0 a
	Na	-	0.02± 0.01 b	0.03 ±0.01 a, b	0.03 ±0.01 a, b	0.03 ±0.0 a	0.03 ±0.0 a	0.02 ±0.01 b	0.02 ±0.0 a, b	0.03 ±0.02 a, b	0.02±0.0.0. a,b
	K	-	0.33± 0.03 c	0.33 ±0.0 c	0.41 ±0.06 a	0.41 ±0.05 a, b	0.3 ±0.04 c, d	0.34 ±0.06 b, c	0.34 ±0.05 b, c	0.25 ±0.01 d, e	0.21 ±0.03 e
	P		0.01±0.0 a	0.01 ±0.0 a	0.01 ±0.0 a	0.01 ±0.0 a	0.01 ±0.0 a	0.01 ±0.0 a	0.01 ±0.0 a	0.01 ±0.0 a	0.01 ±0.0 a
	Ca		0.1±0.02 f	0.12 ±0.03 e, f	0.14 ±0.0 d, e	0.14 ±0.02 d, e	0.15 ±0.01 c, d, e	0.16 ±0.02 b, c, d	0.18 ±0.03 a, b, c	0.18 ±0.0 a, b	0.2 ±0.0 a
	Mg	-	0.12± 0.02 b	0.12 ±0.0 b	0.15 ±0.01 a	0.15 ±0.03 a	0.15 ±0.01 a	0.15 ±0.03 a	0.14 ±0.02 a	0.15 ±0.0 a	0.15 ±0.0 a

Notes: Data presented as mean ± SD (n=3). Values denoted by different letters differ significantly at $p \leq 0.05$.

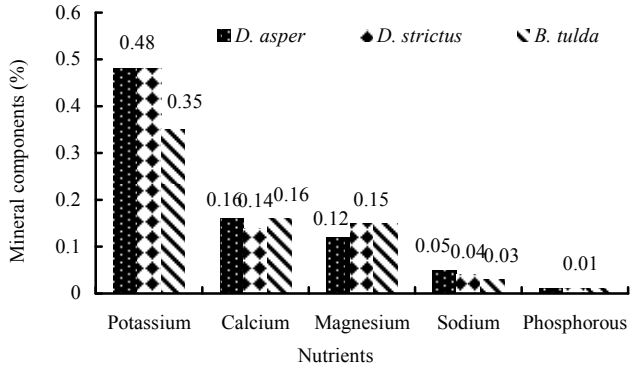

Fig. 3 Variation in mineral components of bamboo shoots at optimum harvesting days

Cyanogen content

The cyanogen content varied significantly (at $p \leq 0.5$) among different species and in different days old shoots. The cyanogen content was minimum in emerging shoots and increased with age/days of the shoot harvested (Table 4). Many edible plants contain cyanogenic glycosides, whose concentrations vary widely as a result of genetic and environmental factors, location, season, and soil types (Ermans et al. 1980; JECFA 1993). Haque and Bradbury (2002) also reported minimum cyanogens content in the emerging shoots. An increase in the cyanogens content of bamboo shoots with age was also reported by Anonymus (2004), Fu et al. (2002) and NMBA (2004). Hoarongban et al. (2010) also reported that the cyanogens content had an increasing trend in the middle portion of bamboo shoots with ages. This indicates

that the freshly/newly emerging shoots are nutritionally superior to older shoots. Generally, plants containing more than 20 mg cyanogen per 100 g of fresh plant material are considered potentially dangerous for human consumption (Kingsbury 1964).

European Food Society Authority (EFSA 2004) stated that the level of up to 10 mg·kg^{-1} HCN is not associated with acute toxicity. The continuous exposure of HCN through diet may lead to pancreatic diabetes (Kamalu 1995). Jansz and Uluwaduge (1997) reported that people eating foods containing cyanide for long time developed damage to the central nervous system and the thyroid gland. Thus, the cyanide content in the bamboo shoots could prove potentially toxic for the humans. Hence, shoots should be harvested at right stage of maturity to avoid cyanide toxicity.

Table 4. Cyanogens content (g·100g^{-1}) in shoots of *Dendrocalamus asper*, *D. strictus* and *B. tulda* at different optimum harvesting ages

Species	2 day	4 day	6 day	8 day	10 day	12 day	14 day	16 day	18 day	20 day
D. asper	-	-	-	0.016 ± 0.001 a	0.018 ± 0.000 b	0.019 ± 0.001 b	0.018 ± 0.000 b	0.020 ± 0.002 c	0.021 ± 0.001 c	-
D. strictus	0.01 ± 0.0 a	0.01 ± 0.001 a	0.015 ± 0.001 b	0.015 ± 0.0 b	0.015 ± 0.0 b	0.021 ± 0.001 c	0.03 ± 0.004 d	0.032 ± 0.003 d	-	-
B. tulda	-	0.022 ± 0.01 a, b	0.02 ±0.01 a	0.02 ±0.0 a	0.021 ±0.0 a	0.02 ± 0.01 a	0.02 ±0.0 a	0.022 ±0.01 a, b	0.025 ±0.04 b, c	0.025 ±0.04 c

Notes: Data presented as mean ± SD (n=3). Values denoted by different letters differ significantly at $p \leq 0.05$.

Phenolic acids

Significant variation (at $p \leq 0.5$) was observed in the concentration of phenolic acids. Concentration of gallic acid was initially increased in *D. asper* (from 0.048-0.067 mg·g^{-1}). Caffeic acid increased in all the species with the shoot ages. Vanillic acid increased in *D. asper* (from 0.009−1.262 mg·g^{-1}) and *D. strictus* (from 0.273−2.563 mg·g^{-1}) while it decreased in *B. tulda* (from 4.483−0.61 mg·g^{-1}) with the ages of shoots. Chlorogenic acid initially increased and then decreased in all the three species (Table 5). Several studies indicated that the antioxidant activities of some plants are highly correlated with their phenolic contents (Palav et al. 2006; Oboh 2008; Gupta et al. 2010). Therefore, the bamboo shoots can also be used for formation of natural antioxidants. Pandey et al. (2011b) also reported that phenolic acids have a correlation with antioxidant properties.

Table 5. Phenolic acid composition in shoots of *Dendrocalamus asper, D. strictus* and *B. tulda* at different optimum harvesting ages (mg·g^{-1})

Species	Constituent	2 day	4 day	6 day	8 day	10 day	12 day	14 day	16 day	18 day	20 day
D. asper	Gallic acid	-	-	-	0.048 ± 0.017 a	0.052 ± 0.020 a	0.057 ± 0.017 a	0.067 ± 0.023 a	0.067 ± 0.015 a	0.067 ± 0.031 a	-
	Chlorogenic acid	-	-	-	0.077 ± 0.022 d	0.183 ± 0.018 c	0.277 ± 0.025 c	0.58 ± 0.026 b	0.29 ± 0.020 b	0.184 ± 0.027 a	-
	Vanillic acid	-	-	-	0.009 ± 0.015 c	0.02 ± 0.011 c	0.22 ± 0.020 c	0.47 ± 0.016 b,c	0.88 ± 0.017 a,b	1.262 ± 0.018 a	-
	Caffeic acid	-	-	-	0.382 ± 0.019 f	0.508 ± 0.012 e	0.665 ± 0.033 d	2.07 ± 0.023 c	4.41 ± 0.026 b	4.47 ± 0.028 a	-
D. strictus	Gallic acid	0.040 ± 0.012 f	0.059 ± 0.015 e,f	0.072 ± 0.023 d,e,f	0.088 ± 0.026 c,d	0.102 ± 0.030 b,c	0.126 ± 0.014 a,b	0.144 ± 0.022 a	0.173 ± 0.020 a	-	-
	Chlorogenic acid	0.092 ± 0.042 g	0.143 ± 0.032 f	0.306 ± 0.024 e	0.42 ± 0.020 d	0.99 ± 0.020 a	0.89 ± 0.030 b	0.631 ± 0.016 c	0.464 ± 0.018 d	-	-
	Vanillic acid	0.273 ± 0.032 g	0.598 ± 0.024 f	0.805 ± 0.019 e	0.993 ± 0.022 d	2.01 ± 0.018 c	2.222 ± 0.018 b	2.436 ± 0.021a	2.563 ± 0.016 f	-	-
	Caffeic acid	0.258 ± 0.022 g	0.466 ± 0.032 f	0.575 ± 0.035 e	0.613 ± 0.028 e	0.782 ± 0.017 d	0.974 ± 0.022 c	1.19 ± 0.018 b	1.317 ± 0.020 a	-	-
B. tulda	Gallic acid	-	0.041 ± 0.015 e	0.056 ± 0.019 d, e	0.076 ± 0.019 c,d	0.085 ± 0.030 c,d	0.105 ± 0.021 b,c	0.112 ± 0.017 b,c	0.25 ± 0.021 a	0.127 ± 0.016 b	0.129 ± 0.013 b
	Chlorogenic acid	-	0.02 ± 0.013 h	0.112 ± 0.017 e,f	0.72 ± 0.013 b	1.6 ± 0.017 a	0.53 ± 0.015 c	0.36 ± 0.014 d	0.121 ± 0.012 e	0.091 ± 0.022 f	0.052 ± 0.019 g
	Vanillic acid	-	4.483 ± 0.018 a	3.4 ± 0.017 b	3.05 ± 0.019 c	1.84 ± 0.015 d	1.67 ± 0.025 e	1.1 ± 0.020 f	0.925 ± 0.013 g	0.732 ± 0.016 h	0.61 ± 0.021 i
	Caffeic acid	-	0.423 ± 0.015 i	0.55 ± 0.021 h	0.68 ± 0.026 g	0.82 ± 0.020 f	1.02 ± 0.015 e	1.183 ± 0.021 d	1.326 ± 0.015 c	1.41 ± 0.017 b	1.582 ± 0.018 a

Notes: Data presented as mean ± SD (n=3). Values denoted by different letters at differ significantly $p \leq 0.05$.

Although the freshly emerging shoots have less productivity than the older shoots, there is more nutrient content in shoots, as they start emerging from the ground. The results of Duncan's Multiple Range Test revealed that optimum harvest age for *D.*

asper was at 10–14 days old, for *D. strictus* at 6–10 days old and for *B. tulda* at 10–16 days old shoots.

Conclusions

The present study concludes that it is better to harvest *D. asper*, *D. strictus* and *B. tulda* within 10-14 days, 6-10 days and 10-16 days old respectively, when their shoots had richer nutritional composition and lesser concentration of cyanides. From the perspective of human nutrition, bamboo shoots harvested on above mentioned days can be of good nutraceutical/therapeutic value, which are low in calories and cyanogens, contain good amount of carbohydrates, proteins and rich in minerals such as potassium, calcium and magnesium. The older shoots are woody with low palatability and digestibility. Bamboo shoots hold the prospect of value added economic activity at industrial and society levels through cultivation, processing, packing and commercialization. Shoots harvested at right maturity will augment their marketability and utilization values. The findings of the study may further be valuable for use in food composition database and prevention of diseases caused by cyanide toxicity due to consumption of bamboo shoots.

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